Gasification of Biorefinery Residues

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David C. Dayton
National Renewable Laboratory

Presentation Outline

biomass program

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Project Background

Gas cleanup requirements will be dictated by biorefinery residue compositions that are a function of feedstock and pretreatment/process conditions

Barriers Addressed: Reducing Integrated Biorefinery product costs by defining a higher-value use for lignin-rich residues and off-spec biochemical conversion feedstocks

Gas Cleanup Impacts

	N	S	Cl	Alkali	Tars	Syngas Quality
Corn Fiber	*M-H*	*L*	*L*	*L*	*?*	*?*
DDGS	*H*	*M*	*M*	*M*	*?*	*?*
Corn Fiber	M-H	L	L	L	?	?
Lignin*	M	L	M-H	M-H	?	?
Others…						

*Depends on pretreatment and process conditions

Project Overview

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Stage Placement – Stage A

Supports other projects and provides information for the design and operation of pilot-scale systems and technoeconomic analyses

Project Objective

To ensure that biomass gasification technologies are compatible with the production of fuels and chemicals based on technologies currently available to facilitate the development of a vigorous industry based on biorefinery concepts to produce liquid transportation fuels and chemicals from biomass.

Effect of Gasification Processing on Biochemical Conversion Residues Composition

Benchmark parametric corn stover gasification studies in NREL TCPDU with a new feedstock to evaluate syngas quality for Integrated Catalyst Studies Task.

Pathways and Milestones – C-level and Project Milestones

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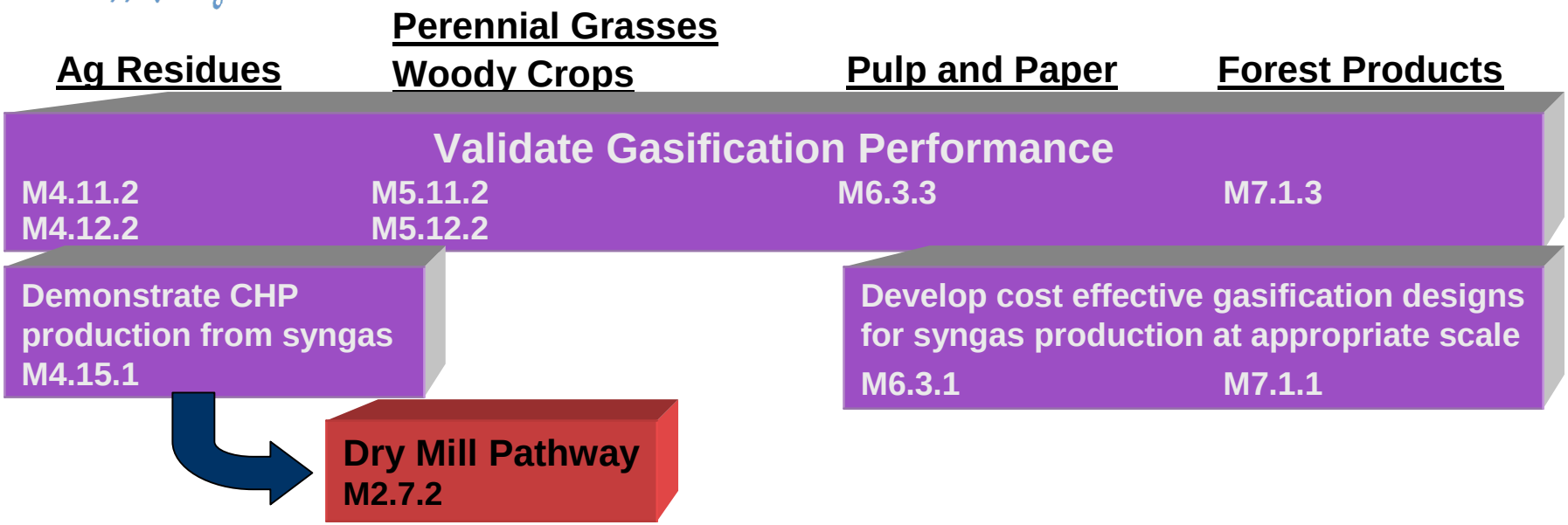

Project Milestones	Type	Performance Expectations	Due Date
Syngas Quality from Gasification of Biorefinery Residues	D	Identify key process and operating parameters that control tar formation and potential product selectivity by measuring selected biorefinery residues	Sept. 2005

Technical Feasibility and Risks

- Bench-scale and Pilot-scale studies provide fundamental data for relatively low cost and low risk
- Can explore a wide range of experimental conditions a in reasonable time frame to focus process optimization of demonstration projects
- Challenge: Develop correlations that apply to larger-scale systems

Competitive Advantage

Gasification vs. Combustion of Lignin-rich Residues

- Improved efficiency of biomass utilization
- Higher liquid fuel yields per biomass input
- Improved CHP production efficiency
- Syngas as a natural gas replacement

History and Accomplishments

- Builds on past bench-scale studies
- Collected 14 representative residues/feedstocks
  - 10 corn stover varieties
  - Corn stover used in TCPDU studies
  - Wheat straw
  - NREL Corn Stover Biochemical Conversion Residue (lignin)
  - Forest residue
- Fuel analyses being completed for all collected samples
- Parametric Corn Stover Gasification in NREL TCPDU
  - 7 tons corn stover from Imperial, NE (S. Thomas NREL)
  - Pelletized by Sebs Feed and Supply in Tarreton, ID (R. Hess INL)

Feedstock Fuel Variability

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Feedstock Composition			
	Wood	Corn Stover	BioChem Residue
Proximate Analysis (wt %)			
Moisture	3.74	5.78	0 (63.76)
Ash	0.63	10.69	14.02
Volatiles	82.68	67.35	60.25
Fixed C	12.95	16.18	25.73
Ultimate Analysis (wt%)			
C	51.36	44.0	55.95
H	6.25	4.68	5.20
N	0.11	0.68	2.27
O	37.89	34.09	22.37
S	0.02	0.08	0.19

NREL TCPDU Syngas Composition (S/B = 1)			
Vol%	Wood	Corn Stover	BioChem Residue
H_2	28.1	25.4	?
CO	25.5	23.4	?
CO_2	25.2	22.5	?
CH_4	15.3	14.5	?
C_2H_4	3.7	4.4	?
Benzene (mg/Nm^3)	6,500	10,000	?

NREL's Thermochemical Process Development Unit (TCPDU)

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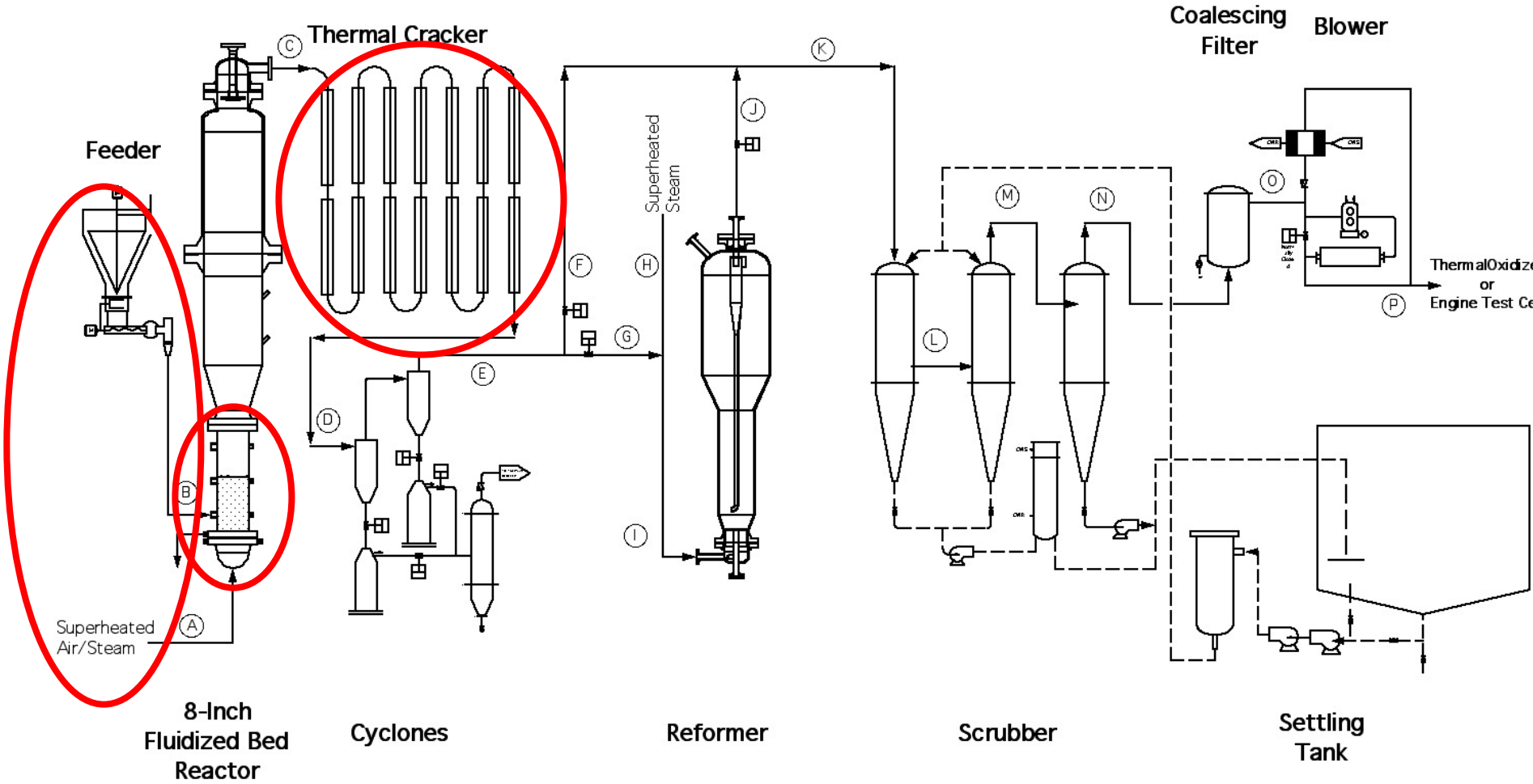
On-line, Real-time Product Gas Analysis

8" Fluidized Bed Reactor

Catalytic Steam Reformer

NREL 150 kWt Thermochemical Pilot Development Unit



On-line Analytical Capabilities

- Non-dispersive infrared (NDIR) Analyzer for CH_4 (range: 0-50 vol%)
- NDIR Analyzers for CO_2 and CO (0-50 vol% range)
- Paramagnetic Oxygen Analyzer (range of 0-25 vol%)
- H_2 thermal conductivity analyzer (range of 0-50 vol% and analog inputs for %CO, %CH_4 and %CO_2 to correct the H_2 value)
- Quad Micro Gas Chromatograph
  - 4 channel, on-line GC with 2-3 min cycle time
  - H_2, O_2, N_2, CH_4, CO, CO_2, C_2H_6, C_2H_4, C_2H_2, C_3H_8, and C_4 paraffin's and olefins
- Transportable molecular beam mass spectrometer (TMBMS)
  - Continuous, real-time monitoring of all gas phase products with particular emphasis on condensible tars and heteroatoms

Baseline Parametric Corn Stover Gasification

- Baseline data for Integrated Catalyst Studies subtask to evaluate 3 tar reforming catalysts in the next 3 months
- A total of 1633 kg of corn stover fed over a ~80 hour period; 1288 kg was fed during 56 continuous hours of statistically designed parametric gasification conditions
- 24 gasification conditions studied for process model development
  - Variables: bed and thermal cracker temperature and steam-to-biomass ratio
  - Desired results: carbon conversion (char yields), gas compositions, tar yields, tar composition, N and S release

Real-time data from corn stover gasification

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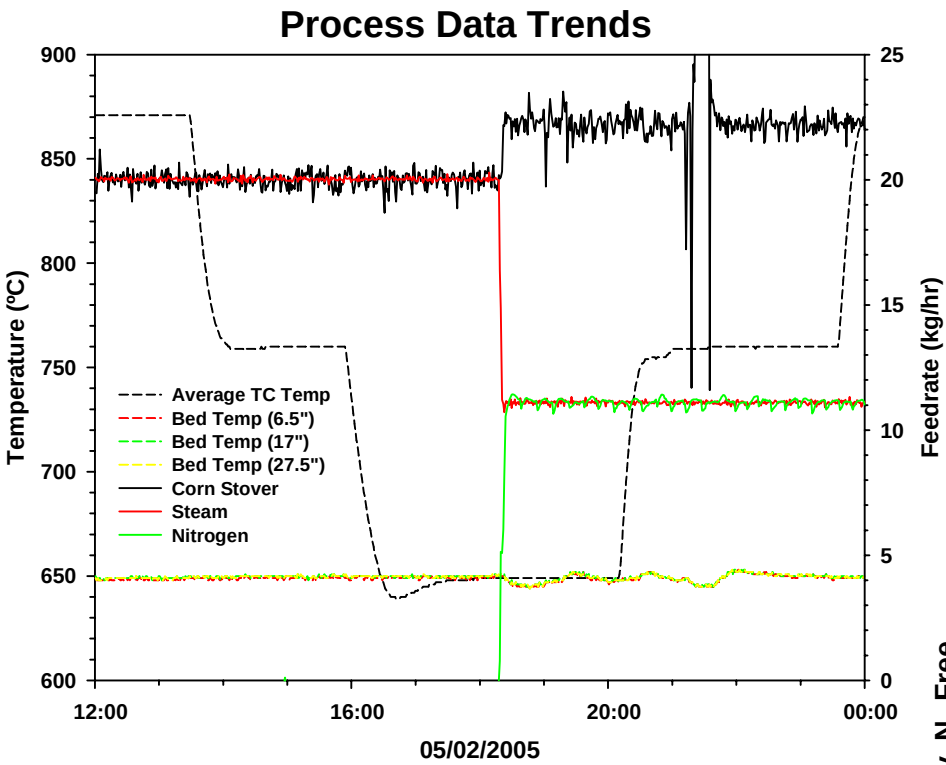

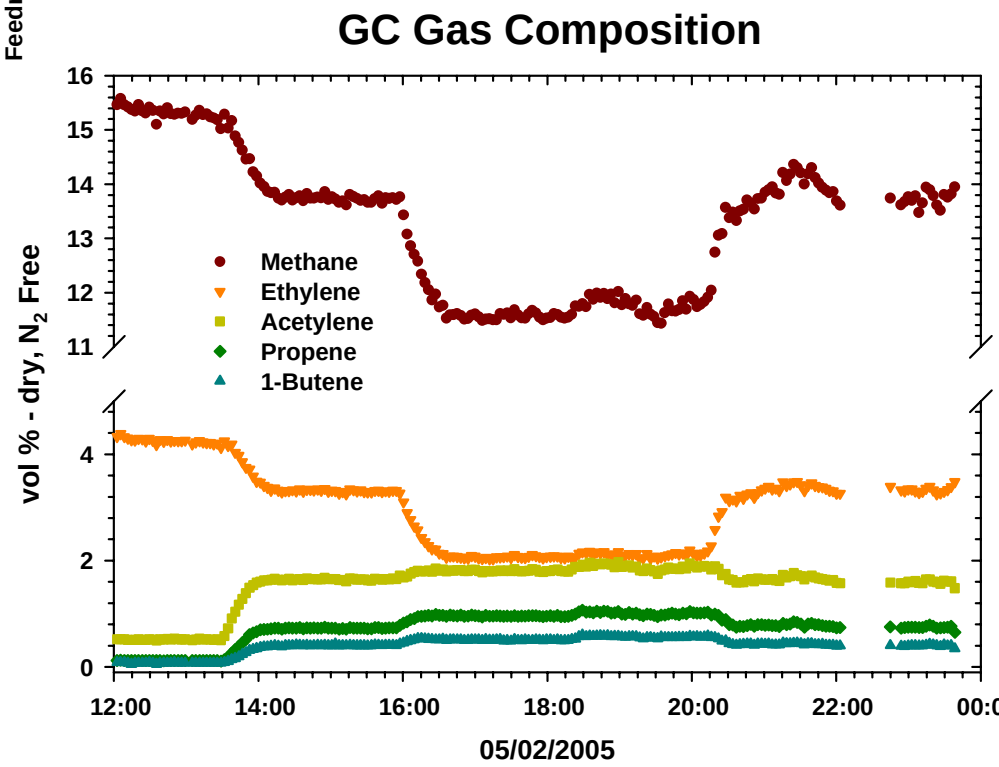

On-line Tar Measurements

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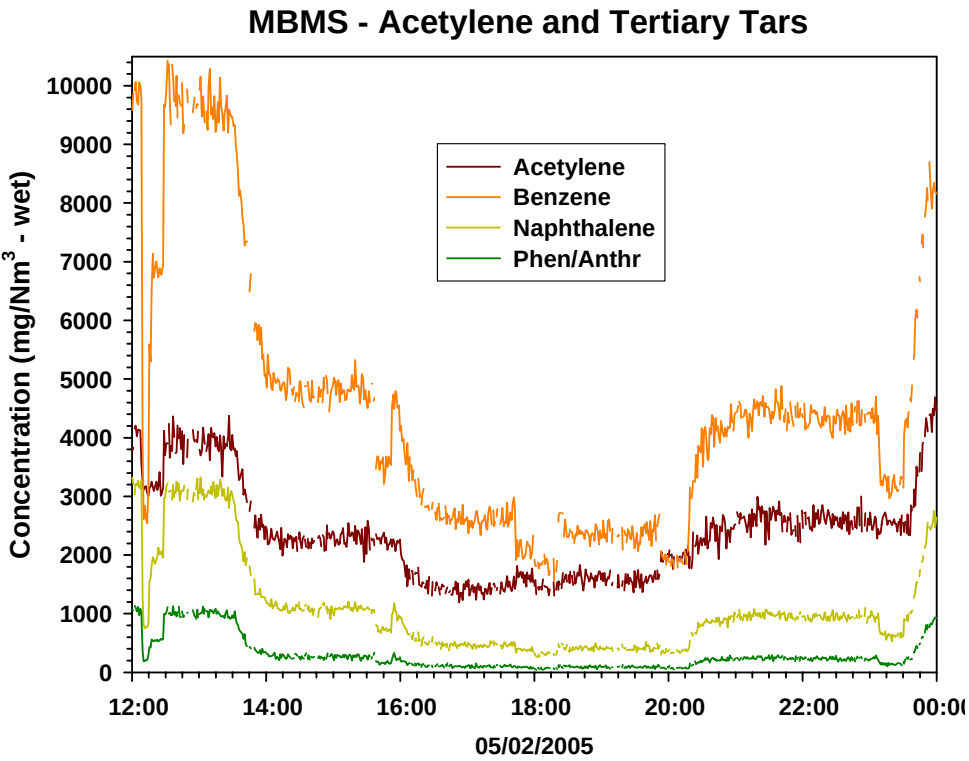

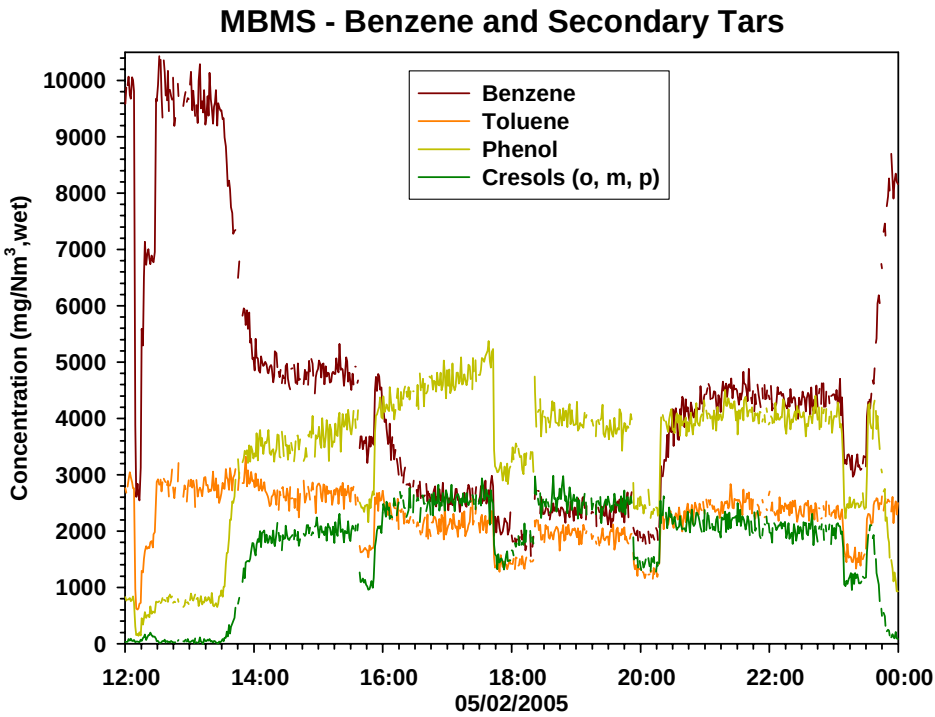

Non-syngas Products

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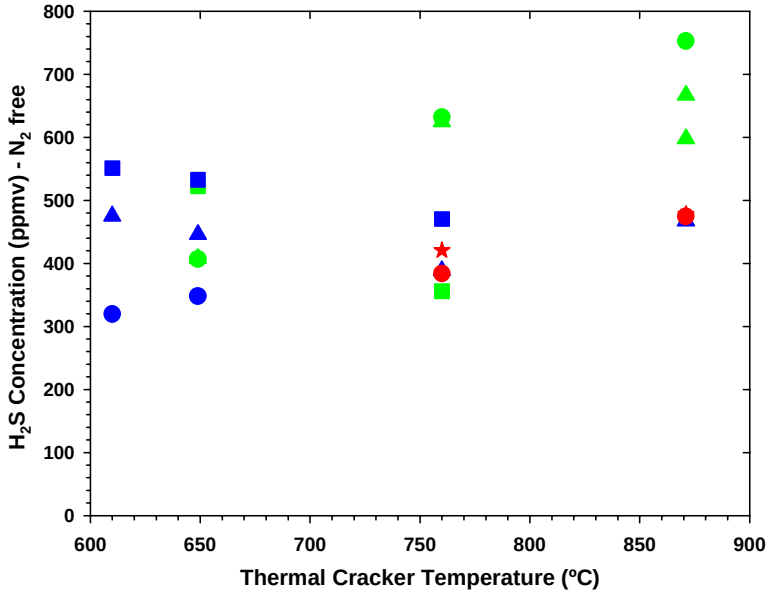
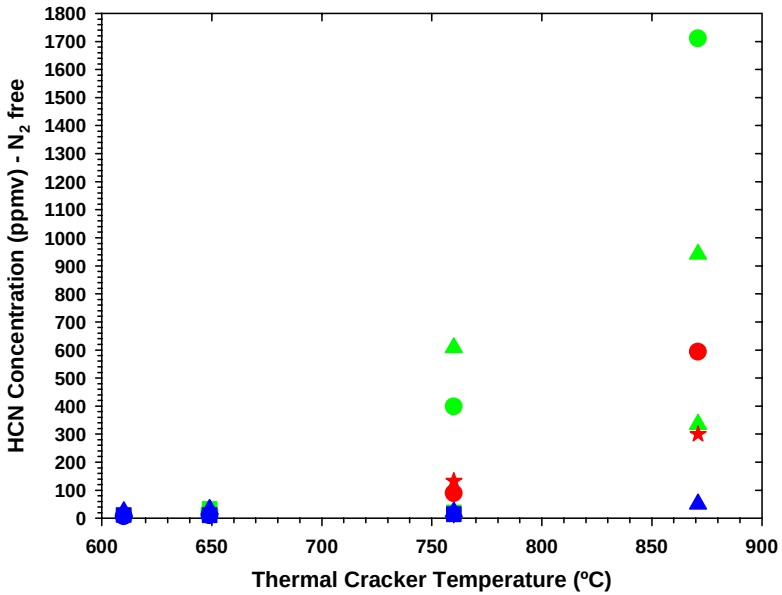
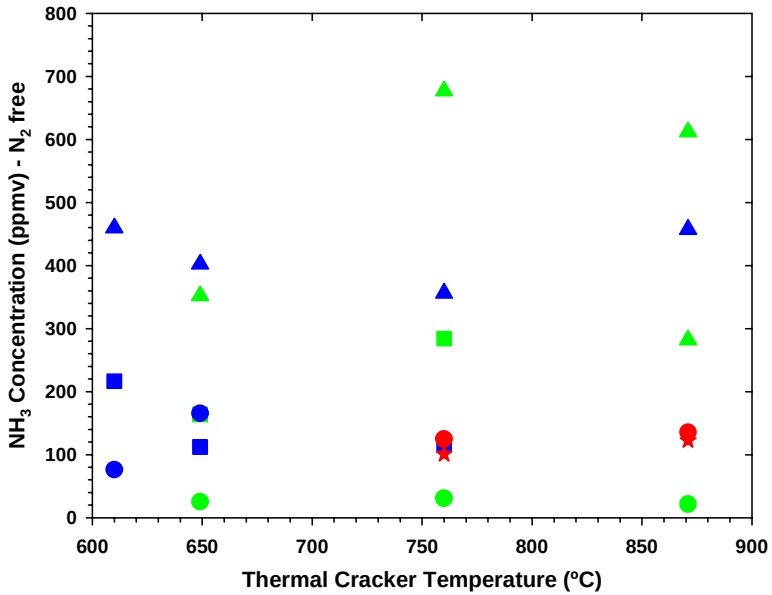
Draeger tube analysis of grab samples taken at each steady-state process condition

- Look for correlations with process conditions
- Need on-line measurement to pH of scrubber water to correlate with HCN/NH_3 solubility in water.
- Need on-line sulfur measurement capability with higher accuracy and precision.







Summary of Results

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24 gasification conditions studied for process model development
- bed temperature – 593, 649, 715ºC
- thermal cracker temperature – 610, 649, 760, 871ºC
- steam-to-biomass ratio – 1, 0.5, 0.33

Continuous GC analysis for permanent gas composition (up to C4's)
- Average gas composition for each steady-state condition

Continuous tar monitoring with MBMS
- Quantified tars: benzene, toluene, phenol, naphthalene, phenanthrene/anthracene

30 solid samples collected for analysis
- 3 feed samples
- 25 char samples
- 2 bed samples

26 syngas grab samples
- offline H_2S, HCN, and NH_3 analysis

ID	Biomass kg/hr	Steam kg/hr	N2 kg/hr	Bed Temp C	TC Temp C	Mass Closure (total)
CS_g1_1.1	20	20	0	649	871	**94.2**
CS_g1_1.2	20	20	0	649	760	**99.0**
CS_g1_1.3	20	20	0	649	649	**107**
CS_g1_2.1	22.2	11.1	11.1	649	649	**105**
CS_g1_2.2	22.2	11.1	11.1	649	760	**106**
CS_g1_2.3	22.2	11.1	11.1	649	871	**103**
CS_g1_3.1	27	9	13.5	649	871	**101**
CS_g1_3.2	27	9	13.5	649	760	**100**
CS_g1_3.3	27	9	13.5	649	649	**100**
CS_g1_3.4	27	9	13.5	593	649	**99.0**
CS_g1_3.5	27	9	13.5	593	610	**100**
CS_g1_3.8	27	9	13.5	593	871	**98.3**
CS_g1_1.4	20	20	0	593	649	**99.2**
CS_g1_1.5	20	20	0	593	610	**102**
CS_g1_2.4	22.2	11.1	11.1	593	610	**101**
CS_g1_2.5	22.2	11.1	11.1	593	649	**108**
CS_g1_2.6	22.2	11.1	11.1	593	760	**99.6**
CS_g1_4.1	15	9	12.5	715	871	**99.9**
CS_g1_3.7	15	11.1	11.1	715	760	**105**
CS_g1_1.6	15	15	7.5	715	760	**103**
CS_g1_1.7	15	15	7.5	715	871	**104**

Plan/Schedule

FY05

- Completed parametric corn stover gasification studies for catalyst testing baseline
- Complete element balances pending solids analysis
- Multivariate analysis of corn stover gasification data to correlation gas composition with process conditions
- Complete bench-scale gasification of collected residues/feedstocks

FY06

- Coordinate with NREL BioProcessing R&D Group (Sugars Platform) to generate enough biochemical conversion residues for full-stream catalyst testing in NREL TCPDU.
- Baseline parametric gasification of lignin-rich residues
- Continue bench-scale gasification studies and integrate with Gas Cleanup and Conditioning projects

Critical Issues and Show-stoppers

- Parametric Corn Stover Gasification studies reinforced the need for on-line (real-time) N and S measurements
  - NH_3 and HCN conversion over reforming catalyst
  - Impact of sulfur (H_2S) on reforming catalyst performance
  - Evaluate commercial sulfur removal options (TC Analysis Project)
- High Ash Content of Biorefinery Residues
  - Catalytic effects?
  - Bed agglomeration vs. Temperature
  - Ash handling

Summary

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- Use pilot-scale data to develop publicly available correlations between process conditions and syngas yield, char yield and syngas composition as input for process simulations of integrated thermochemical processes.
- Provide a gasification test facility for integrated biorefinery developers
  - Corn Stover Residue (lignin) from NREL Biochemical PDU
  - Process residues of commercial interest
  - Commercial feedstocks in BC/TC pilot-scale integrated biorefinery
  - Validation of biorefinery residue gasification as a technology option for natural gas replacement in corn dry mills
- Highlights the impact of sulfur transformation in thermochemical processes
  - Baseline syngas quality data to evaluate future gas cleanup and conditioning requirements and options
- Funding History ($K) FY04 - 327 FY05 - 400

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